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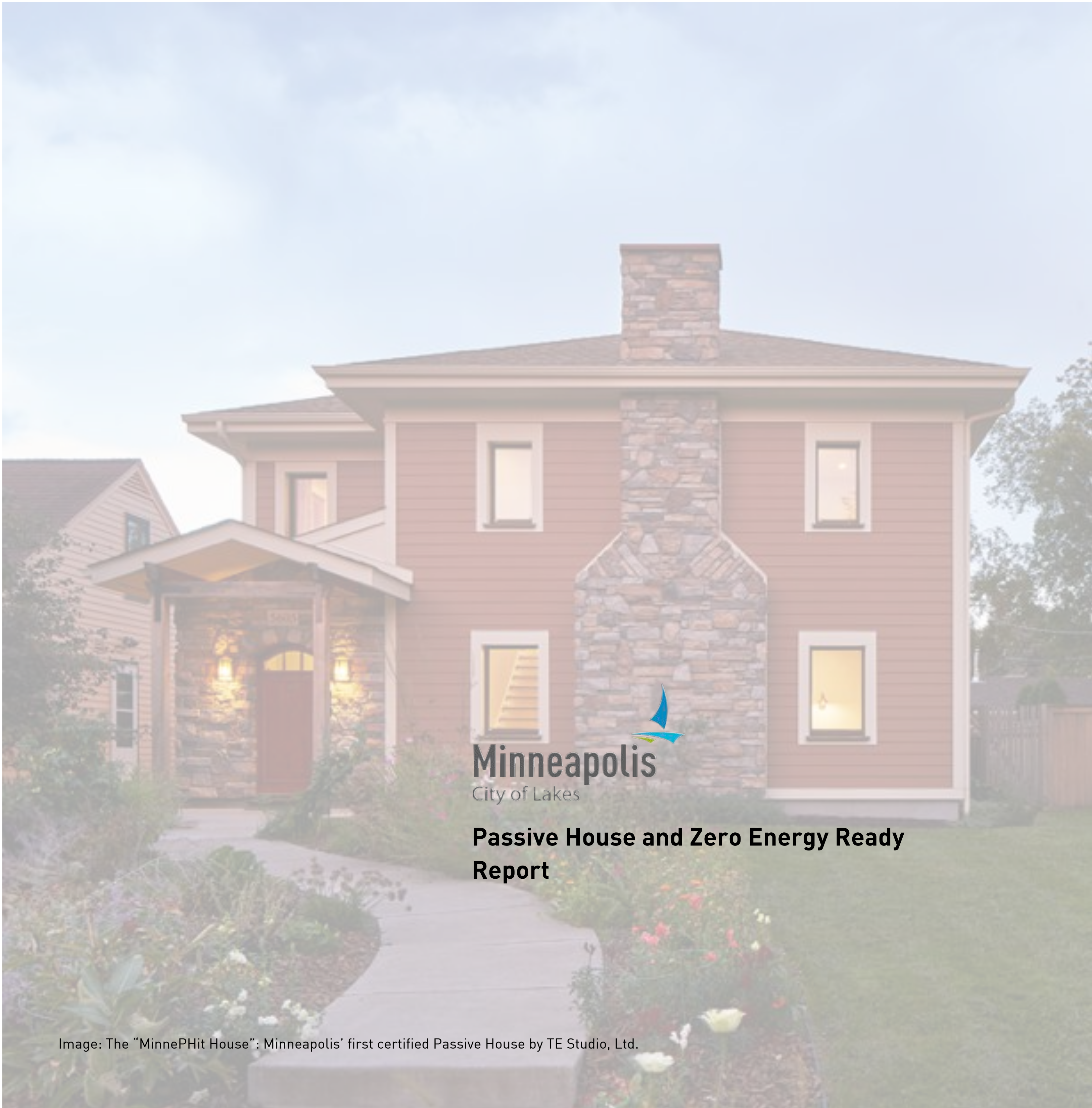

Minneapolis
City of Lakes

Passive House and Zero Energy Ready Report

Image: The "MinnePHit House": Minneapolis' first certified Passive House by TE Studio, Ltd.

Imprint

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Acknowledgements This report references "Fighting Climate Change As A 2000-Watt Society, a Climate Action Framework Plan for Minneapolis" courtesy of the 2000-Watt Society[1]

We thank the Greater Metropolitan Housing Corporation, Curt Bennett and the contractors who answered the RFP for their collaboration to provide costing information for this report.

Disclaimer The information provided in this report as delivered as is.

[1] https://www.2000-watt-society.org

Table of Contents

1 Executive Summary

We outline some of the key findings of our report on this page.

Building Standard Comparison

- The most significant energy load in a Minneapolis home is heating energy. It generally accounts for 2/3 to ¾ of all energy consumed. It is generally delivered with natural gas (a carbon-laden fuel). Heating energy demand is therefore the single most significant deciding factor between building standards in regards to sustainability and climate-neutrality.
- The Passive House building energy standard focuses extensively on heating (and cooling) energy demand, among other comfort, health and durability-related targets.
- Green Communities is a more all-encompassing sustainability standard with a minor energy component compared to Passive House.
- Zero Energy Ready Home focuses mostly on energy production with the help of roof-mounted photovoltaic systems, or preparation for such systems and does not offer a breadth of sustainability measures such as Green Communities.
- In regards to energy, Green Communities and Zero Energy Ready Home reference the same standard: Energy Star for Homes
- Energy Star for Homes is only marginally/ incrementally different from MN building code—offering only about a 10-30% energy efficiency increase in heating energy demand (not overall energy consumed).
- The most significant upgrade of Energy Star homes over Code is a better wall assembly. However, the better wall assembly is not currently being built in Minneapolis Green Communities homes reviewed, which means that current designs are technically not Green Communities compliant and investment cost and energy savings are at the low end of the expected spectrum at about (10% heating energy efficiency over Code).
- The Passive House building energy standard is a leapfrog approach, which offers a 90% heating energy efficiency over Code.
- Zero Energy Ready Home does not require a more energy efficient building to be built than Green Communities; a 2" conduit to the roof for a future photovoltaic solar panel system is sufficient to meet this standards goals.

First-Day Cost

- Costing proved challenging in the local market place.
- Few bidders demonstrated interest in Passive House construction.
- The difference between the low and high bidder for the base building being greater than the investment in the Passive House upgrade!
- The average cost for the base house is $333,6000. The average cost for the Passive House is $395,9000. Average investment cost in the Passive House upgrade are around $65,000.

Energy and Climate Impact

- It would take 2, or more roofs to provide a net-zero energy offset with photovoltaic solar panels for an Energy Star (Green Communities or Zero Energy Ready Home). Therefore, Energy Star homes cannot generally be offset on their own roof surface.
- A Passive House can be offset with photovoltaic solar panels on its own roof surface.

- Energy Star (Green Communities and Zero Energy Ready Home) buildings conserve so little energy that Climate-neutrality means a significant expansion of the clean energy infrastructure.
- Passive House buildings are so energy efficient that the current clean energy infrastructure is sufficient to fuel them, which means their social cost is significantly lower than that of Energy Star homes.

Net-Zero Cost

- Under current conditions and all cost considered, the Passive House is the cheapest project to take to an all-electric, net-zero level of performance.

Challenges and Opportunities for Minneapolis

- Minneapolis leadership and staff need to build an understanding for the orders of magnitude to create a clean energy infrastructure with, and without energy efficiency.
- Minneapolis lacking clear, transparent and uniform targets for energy demand and supply based on one climate action plan for all aspects of civic life. Those targets are required to inform specific building standard (Suggested reference "2000-Watt Society", Framework Plan for the City of Minneapolis).
- Minneapolis needs to create and support pilot projects to build an understanding of energy loads, climate impact and first-day/ life cycle cost to inform a subsequent roll-out with respective funding to demonstrate leadership and to drive down cost.
- Minneapolis needs to train staff, remove internal barriers, educate the market and support local Passive House efforts including training to create a workforce fit for high-performance buildings and true and meaningful climate action.

2 Introduction

It is the goal of this study and report to inform an order of magnitude investment needed to close the first-day cost gap to develop ultra-efficient, climate-neutral, affordable single-family homes. As directed by CPED, this study uses the currently mandated "Minnesota Overlay for Enterprise Green Communities[2]" (Green Communities) standard as a baseline and compares its first-day cost and benefits with minimum Minnesota Building Code (Code), the Department of Energy's Zero Energy Ready Home[3] (ZERH) program, as well as the international Passive House[4] (Passive House) standard.

Green Communities and ZERH require building an Energy Star-compliant home. Energy Star minimally elevates requirements for building envelope insulation values over Code. This leads to a small reduction in heating energy demand. ZERH additionally requires roughed-in infrastructure to enable installation of a roof-mounted photovoltaic solar panel system for energy production.

Passive House was selected based on its internationally demonstrated significant heating energy demand-reduction for buildings—the largest individual energy load in a single-family home in Minneapolis, which is the essential key component for the energy efficiency improvements needed to meet climate-neutrality as stated in the City of Minneapolis' Climate Action Plan[5].

CPED asked local developer Greater Metropolitan Housing Corporation (GMHC) to utilize a typical Green Communities, affordable single-family home as the "baseline building" (Base), as well as their network of builders to solicit public proposals for a ZERH and Passive House version of the same design.

Intep provided schematics and specifications (Addendum Figure 14: Passive House and Zero Energy Ready Home Specifications for Pricing) to illustrate the changes to the Base building to achieve ZERH and Passive House, which were used in public requests for proposal. Intep collaborated with GMHC to educate and assist local builders price alternates. The information provided by the builders is illustrated and used in this study and report, as are the environmental impact and benefit findings we aggregated and analysed.

Three key findings are important to note at the outset to frame this report:

1. Currently, built Green Communities homes do not appear to meet all of the prescribed energy efficiency measures stipulated by the program.
2. Green Communities homes—if built to meet all aspects of the program—only provide a small, incremental energy demand reduction compared to Minnesota Code.
3. At present, it is not possible to generate net-zero "clean energy" offsets for Green Communities single-family homes on their own rooftops, or with the existing grid.

[2] http://www.minneapolismn.gov/www/groups/public/@cped/documents/webcontent/wcmsp-222460.pdf
[3] https://www.energy.gov/eere/buildings/zero-energy-ready-homes
[4] https://passivehouse.com/index.html
[5] http://www.minneapolismn.gov/www/groups/public/@citycoordinator/documents/webcontent/wcms1p-113598.pdf

3 First-Day Cost and Environmental Benefits

Minneapolis leadership and staff are using two metrics to gauge the feasibility of developing affordable single-family Passive House homes:

1. First-day cost difference
2. Environmental benefits—chiefly energy consumption and associated GHG footprint.

3.1 First-Day Cost

As is customary in the Minneapolis market, first-day cost is a big influencer for owners and developers to inform the implementation of improvement measures such as energy efficiency, or GHGreduction. It is often used as a measure for feasibility and success. In reality, however, the fiscal advantage of energy efficiency (and associated benefits) come in different shapes and sizes over time, with first-day cost being an incomplete snapshot of the financial picture of the building over its useful life.

Energy efficiency investments pay back steadily over time starting on day one. Benefits such as much improved comfort, resilience, indoor environmental quality (and associated health benefits), fiscal sustainability, reduced GHG emissions and total cost of ownership savings follow along and stay with the building indefinitely—often with little or no maintenance.

It is, of course, fair to assess first-day cost and use it as one part of an equation to inform policy and strategy. However, it is imperative that first-day cost is paired with an analysis of all associated benefits and life-cycle cost to calculate a complete fiscal picture and make ultimately sustainable choices—particularly for publicly funded affordable housing projects. For future studies and further analysis, we therefore recommend using life-cycle cost analysis (LCA) and life-cycle impact analysis (LCIA) to paint a completer and more accurate financial and environmental impact picture.

3.2 Universal, Transparent Accounting for Climate Action Planning and Implementation

As outlined above, an ultra-energy efficient Passive House provides many benefits, including the key environmental benefit of dramatic heating demand reduction—typically up to 90% over Code. Energy efficiency and climate neutrality are directly linked and often serve as a stand-in for one another with varying units of measure being used for either—at times creating confusion and lack of transparency in project teams, in a community, or on a policy level. Energy and climate action targets therefore need to be universal, transparent and measurable to become actionable, comparable and also for accounting purposes. A universal energy consumption unit greatly helps illustrate orders of magnitude differences between standards, programs, energy resources, as well as consumption and production disparities.

As far as climate-neutrality and GHG accounting go, the metric ton is currently used the world over to illustrate CO_2 footprint and climate action achievements. With electricity generally regarded as the "universal fuel" and the "clean energy" of choice for the future (as it can be produced from renewable, carbon-free resources), one energy consumption unit that rises to the top to account for energy demand and supply is the kWh (kilo Watt hour).

3.3 The Meaning of Climate-Neutrality

The 2000-Watt Society and its local "Woldholders" funded "Fighting Climate Change As A 2000-Watt Society[6]", a climate action framework plan for Minneapolis, which highlights the impact and magnitude called for by the **IPCC's global climate goals [7]to achieve climate-neutrality by 2050:**

- Eliminate the use of all fossil fuels; e.g.
  - no more gas/ diesel fuel stations
  - no more natural gas supply system for heating, hot water, cooking etc.
  - all electricity produced from non-fossil fuel resources
- Establish a CO_2-neutral lifecycle eco/energy supply system
- Sequester excess CO_2 from the atmosphere to reduce to less than 350ppm or other climate-neutral level defined by the IPCC

3.4 Cold Climate Challenge

A universal accounting of Minneapolis' energy demand as suggested in paragraph 3.2 visualizes transparently the consumption by energy resource, the order of magnitude challenge to convert everything to clean-energy (electricity), as well as the significant seasonal heating energy demand we face in our cold climate zone:

- Electricity (All Other): 4,202,230,000 kWh
- Gasoline and Diesel (Mobility): 4,549,710,000 kWh
- Natural Gas (Heating): 7,399,160,000 kWh

The monthly demand illustrated in Figure 1 shows that while electricity, gas and diesel consumption remain somewhat steady over the course of the year, natural gas consumption spikes dramatically in winter months based on the current level of (in)efficiency in the built environment. The heating demand is clearly seasonal, which means it is much more challenging and costlier to replace with ad-hoc, carbon-free "clean energy" (electricity = peak load issue)—particularly during a time of the year when renewable resources such as solar electricity are available (due to shorter days with less available sun hours).

[6] https://www.2000-watt-society.org
[7] https://www.ipcc.ch

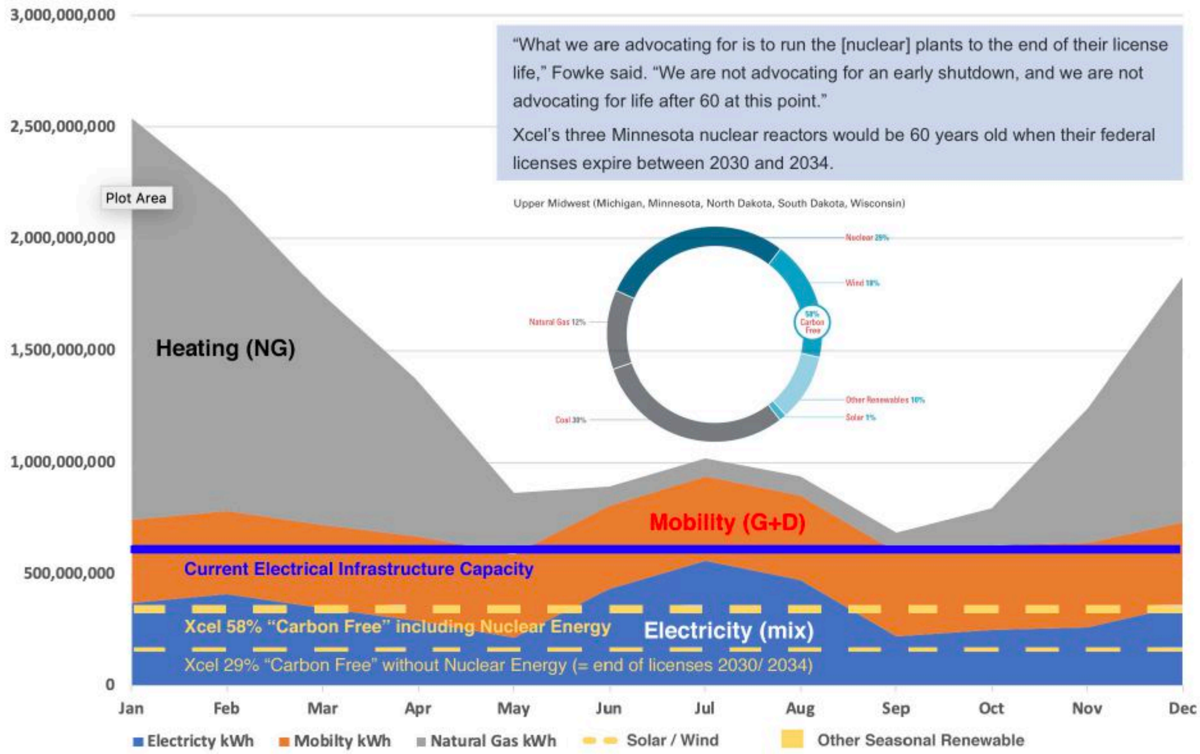

Figure 1: Minneapolis Energy Demand 2010

Minneapolis' current Climate Action Plan focuses on "clean energy", which means a replacement of natural gas with carbon-free electricity. Figure 2 plots the current energy demand and overlays it with the current clean energy production. It therefore represents a shift in technology to an all-electric infrastructure without significant improvements in energy efficiency—clearly illustrating a spike in winter demand.

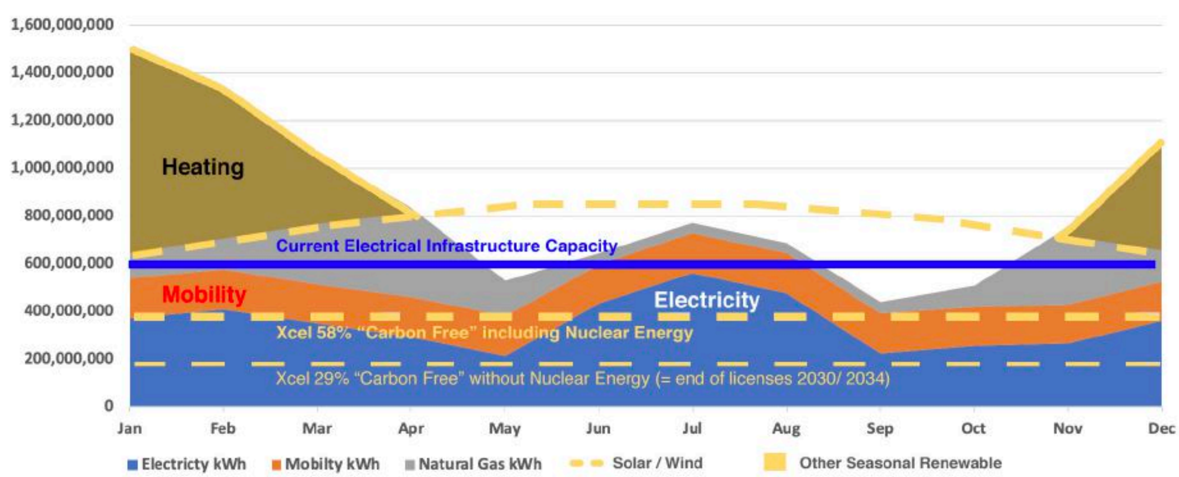

Figure 2: Minneapolis Climate Action Plan as currently stated (all "clean energy")

At present, only about one third of the electricity provided by Xcel Energy registers as "clean energy", not including nuclear power (note that operating permits expire in the 2030s). However, overlaying current production capacities with actual monthly demand illustrates that "clean energy" in general is not the only challenge. Winter heating demand creates a significant need for an increase in seasonal (winter) "clean energy infrastructure". Different demand loads require short/ mid-term and seasonal storage capacities integrated with centralized and decentralized supply generation, which comes at a market price with market-based fees. As such, a climate action plan requires a detailed understanding of both demand and supply with a particular eye on peak loads. For the City of Minneapolis, Figure 1 and Figure 2 illustrate that the massive heating energy demand in cold winter months necessitates "demand management".

Understanding this paradigm, it becomes clear why European countries have studied and implemented ultra-efficient building energy codes—like Passive House—to reduce heating energy demand dramatically by 90%.

The application of Passive House to all buildings in Minneapolis as shown in Figure 3 (only hypothetically possible by 2050 with current construction market capacity[8]) illustrates the dramatic reduction in winter peak heating demand, and how a true resilient clean energy vision could become a reality.

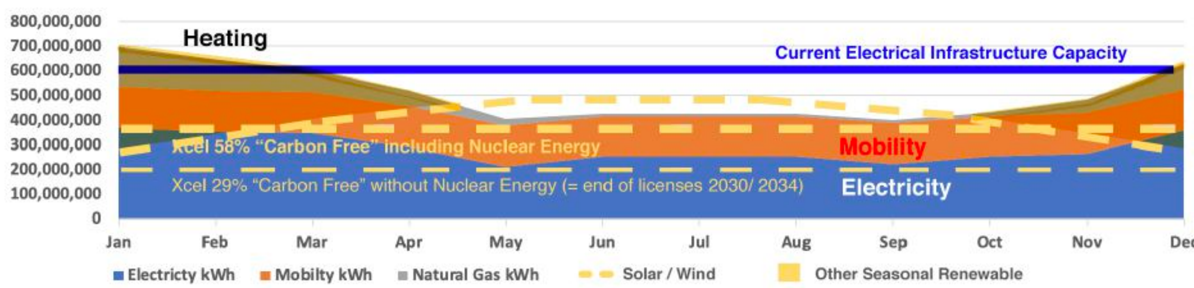

Figure 3: Minneapolis Climate Action Plan with Passive House buildings

Utilizing the 2000-Watt Society targets and moving the City of Minneapolis from an 8000-Watt[8] to a 2000-Watt Society—a true cultural shift as shown in Figure 4—enables an ultimately sustainable lifestyle with today's clean energy supply being almost sufficient to power it.

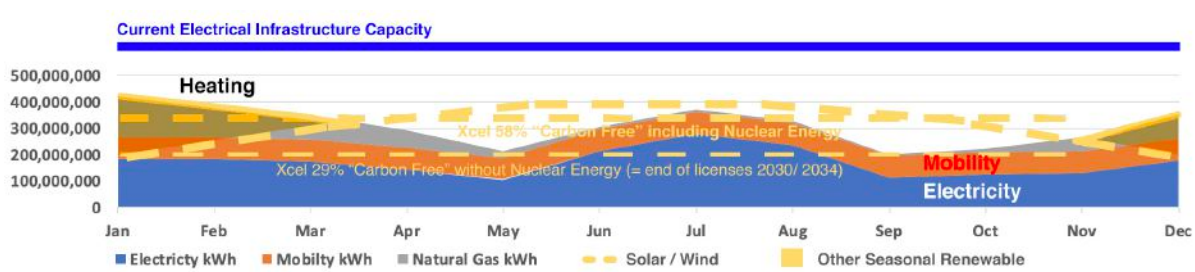

Figure 4: Minneapolis Climate Action Plan based on 2000-Watt Society (comprehensive energy efficiency and sufficiency in all sectors of life and business)

[8] "Fighting Climate Change As A 2000-Watt Society" https://www.2000-watt-society.org

3.5 A Strategic Approach to Climate-Neutrality

To satisfy both winter heating demand and achieve climate-neutrality cost-effectively, Minneapolis can utilize three key principals as outlined by the 2000-Watt Society to successfully overcome the cold climate challenge outlined in paragraph 3.4:

1. Energy Efficiency
2. Sufficiency
3. Clean Energy Infrastructure

Energy Efficiency

The international Passive House standard is leading the charge globally in regards to ultra-energy efficient buildings in part due to its very low heating energy demand targets. Our firm has been spearheading these efforts in North America and the Midwest in numerous projects including the very first certified Passive House project in North America—the Waldsee BioHaus in Bemidji, MN 2005, the City of Vancouver's Action Framework Plan 2012/13, the State of South Dakota's Passive House for public buildings 2014, the Ultra-Efficient Housing strategy for the Minneapolis Public Housing Authority 2017/18, as well as many private projects.

The common finding is that the strategic approach of dramatic reduction of heating energy demand (by up to 90%) paired with sufficiency and clean energy infrastructure serves as the foundation for a successful climate action plan while reducing life-cycle ownership costs.

Sufficiency

In the affordable housing realm, further enhancements come from sufficiency. Understanding that the focus of this report is affordable single-family housing, we offer that a review of the sizing of units, as well as the clustering of units (multi-family versus single family housing) offers additional and significant reduction of the per-unit first-day and life cycle ownership cost, as well as the associated GHG emissions. Work in this realm was completed for the Minneapolis Public Housing Authority[9], which also illustrates improvements beyond the simple function of shelter in terms of communal opportunities for change and leadership.

[9] Minneapolis Public Housing Authority – Ultra Efficient Housing Pilot Projects Report, Intep – Integrated Planning

Figure 5: Waldsee BioHaus, Bemidji, MN 2005; First certified Passive House building in the Americas

3.6 Total and True Cost of Climate-Neutrality

Understanding that the focus of this study is on first-day cost comparisons, we offer that the total cost of climate-neutrality varies greatly based on the approach. Table 1 below illustrates the differences in the total cost of climate-neutrality between the current business as usual Green Communities (first-day cost paradigm) and Passive House (life cycle cost and energy efficiency paradigm). With limited public funds available and on a policy level, it is imperative to select the most effective and sustainable path to invest once, and invest right.

Table 1: Total and true cost of Climate-Neutrality

Cost	Base Building	Passive House[10]
First-day cost for building	$334,000	$396,000
Future retrofit from natural gas to "clean energy" (renewable electricity)	$25,000	$0
Solar PV offset for annual net-zero[11]	$77,800	$35,080
Total cost for annual net-zero	$436,800	$431,080
Annual energy cost 2020 (2050)	$1,920 ($2,400)	$1,284 (same)
"Clean energy" infrastructure upgrade and build out to satisfy peak demand	$$$ to $$$$	$ to $$
Total cost of Climate-Neutrality	**High to Very High**	**Low to High**

10 Pilot project cost (not production building cost)
11 Cost of energy, social cost of carbon, and cost of photovoltaic system provided by the City of Minneapolis

In light of this understanding, the objective and narrow focus of this study to explore and understand the first-day cost of the investment in affordable Passive House homes may not be the best question to ask, as the total and true cost of climate-neutrality—which is also born by society as a whole—is very different from this initial cost marker. While its benefits fit the vision for a sustainable climate-neutral future, it is imperative to build a broader understanding for the "why" in the public realm and on a policy-level.

We therefore suggest the consideration of associated, overarching climate action efforts, City policies, and a fundamental shift of perspective based on the fact that successful climate action starts with the elimination of all fossil fuels in Minneapolis by 2050.

This means the fundamental societal and policy choice whether to primarily invest in:

The replacement of all non-renewable energy with clean energy, resulting in substantial energy infrastructure investment cost with high operating cost, energy dependence and little resilience

OR

The reduction of energy demand with the help of efficiency and sufficiency to dramatically reduce energy infrastructure investment cost with lower operating cost, energy independence and greater resilience

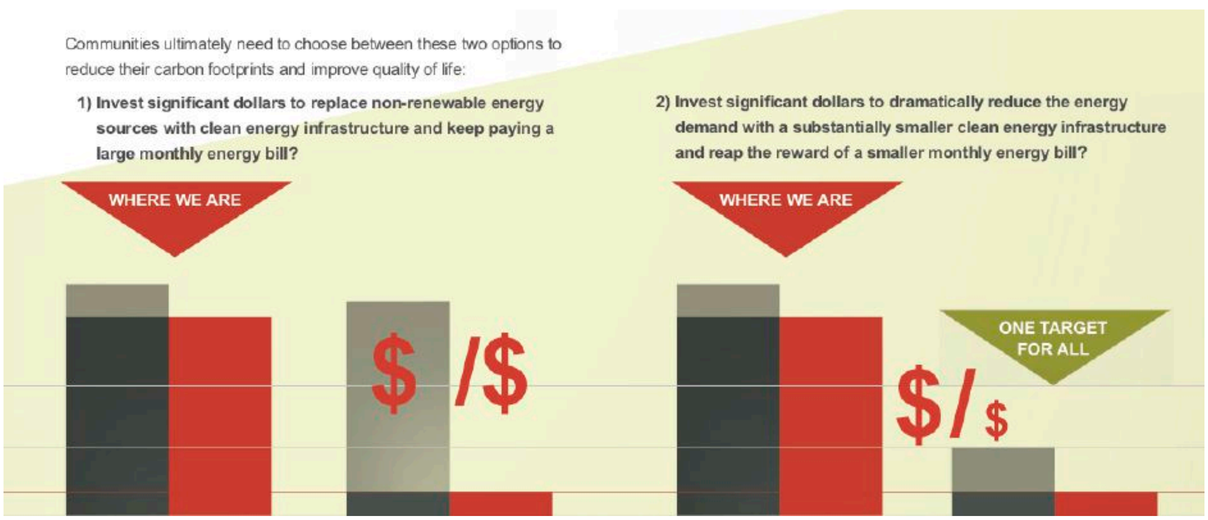

Figure 6: 2000-Watt Society: What society do we want to be and where do we invest?

We recommend that based on this fundamental decision, a group of experts develop a detailed, transparent and accountable assessment of current energy demand in buildings (and other sectors), and to amend the Climate Action Plan with clear and transparent efficiency and sufficiency targets and actions alongside a clean energy infrastructure action plan that can meet future energy demand.

Based on this plan, programs selected and implemented by CPED such as Passive House and ZERH can then become "trail blazers" and "lighthouse projects" for the entire housing market in the City.

4 Comparison Study

4.1 Programs Compared

CPED asked Intep to compare the following standards and programs:

- Minnesota Overlay for Enterprise Green Communities (Base)
- Minnesota Energy Code (Code)
- Department of Energy Zero Energy Ready Home (ZERH)
- International Passive House (Passive House)

Building energy requirements are regulated by the current Minnesota State Building Energy Code (2012 IECC with amendments: effective 2/14/2015). The Minnesota State Building Energy Code can either be achieved by prescriptive target, or by a defined calculation method. In almost all instances the prescriptive method is used by architects, builders and code officials to design, specify, construct and regulate the residential home construction market.

The Passive House standard revolves around a universal calculation method. However, it is conceivable to draw prescriptive targets from it for specific climate zones, regions, or the City, and "localize" the performance parameters in a simplified catalogue.

Any local jurisdiction has the opportunity to improve the energy requirements for their own construction projects, or construction projects they partner on (for instance through funding). As such, the residential project energy performance target for publicly funded projects is currently elevated to Green Communities. With a plethora of voluntary building energy standards in the market place, CPED requested to investigate the ZERH program and put it into perspective with Green Communities, Passive House and code in this report. In theory, and once adopted, any of these programs could therefore become the selected standard for publicly funded affordable housing.

4.2 Approach

CPED asked local developer Greater Metropolitan Housing Corporation (GMHC) to utilize a typical Green Communities, affordable single-family home as the "baseline building"[12] (Base), as well as their network of builders to solicit public proposals for a ZERH and Passive House version of the same design.

We met with the stakeholders to review options identified in a pre-design comparison study and finalized which to include in schematic design and specifications (Addendum Figure 11: Comparison Matrix).

We provided schematics and specifications (Addendum Figure 14: Passive House and Zero Energy Ready Home Specifications for Pricing) to illustrate the changes to the Base to achieve ZERH and Passive House, which were used in public requests for proposal. We utilized our design experience as well as the Passive House Planning Package (PHPP) energy model to create different assemblies and systems for pricing:

1. Green Communities base building (GMHC specifications)
2. ZERH building requirement updates

[12] External reference: GMHC RFP and plans

3. Passive House updates[13]

The Base building and finishes were left untouched making this a fair and reasonable apples-to-apples comparison with itemized deducts and add-ons.

Following the creation of schematics and specifications, we collaborated with GMHC on a couple of rounds of engagements to educate and assist local builders price Passive House deducts and additions. The information provided by the builders is illustrated and used in this study and report, as are the environmental benefit findings we aggregated and analyzed.

4.3 Market Conditions

It is to note that building program targets and guidelines were used for initial analysis while the comparison study utilizes actual building components used on the GMHC Base home. They may be perceived as the same but they are not for two main reasons:

1. It is customary to use the R-value printed on the insulation product as a stand-in for the insulation value of an assembly. However, most assemblies are not uniformly made from insulation and therefore the material R-value of insulation is not the same as the R-value for the entire assembly.
2. Certain standards require a specific installation quality like "Grade 1" for insulation installation. However, the required quality may not be "market typical" and as such, there are very few projects that would be able to achieve this outcome, the costs for such an installation may not meet budget expectations. In addition, the necessary compliance audit on site, or performance testing is not included in the budget and typically not performed.

Green Communities homes are not currently certified by a third-party, meaning that it is only assumed that the built homes are in compliance with the minimum requirements. Herein lies a risk for the funders, developers and planners. We offer that with decades of "value engineering" in the Minneapolis market place to get to the lowest first-day cost, the industry has perhaps also "valued-engineered away" know-how and experience in quality construction and lacks in general the building science knowledge to readily execute very energy efficient housing without strong and skilled guidance.

We observed that the market appeared pretty busy during this study. Interest by builders to answer an RFP was very low. The first round was only answered by 2 companies, followed by 2 more in a second round. Most replies were not entirely complete.

Some builders expressed upfront concerns to produce high-performance buildings and therefore declined to participate in an RFP while others responded that they were too busy, or preferred working on "conventional" projects.

[13] Due to the fact that site conditions impact the actual project-specific outcome, the specifications provided are generalized and may not meet Passive House certification criteria in all instances

Figure 7: Good Energy Haus - Minneapolis' first certified new construction Passive House under construction in 2019

Figure 8: Good Energy Haus - nearing completion in 2020

5 Analysis and Observations

5.1 Green Communities, Zero Energy Ready Home and Passive House

Green Communities and **Zero Energy Ready Home** reference the Department of Energy's Energy Star for Homes[14] program. Those targets are prescriptive for individual components but do not directly address comfort, resilience, overall building energy performance, cost efficiency, total cost of ownership, or climate neutrality.

In comparison to Code, Green Communities and ZERH provide at best a 20-30% reduction in heating energy demand. With the Base building forgoing a better wall assembly, efficiency is increased only about 10% over Code. While further improvements are encouraged, they are not mandated by either program and therefore not typically delivered, making Green Communities and ZERH buildings in general very similar in energy performance to Code buildings. They constitute an incremental performance improvement that does not make a significant step towards improving a clean-energy supply infrastructure requirement on the path to climate-neutrality, or life cycle cost optimization. On the flip side, there is little actual first-day cost to comply with Green Communities and Zero Energy Home Ready making these programs very accessible.

Perhaps the biggest cost driver within the referenced Energy Star program (and thereby Green Communities, or ZERH) in Minneapolis' climate zone is a better wall assembly. However, the labor effort of making the Energy Star wall is similar to the effort of making a Passive House wall, albeit with lesser amounts of insulation material cost. It is expected that labor cost is the lion share of the added cost for a high-performance wall—perhaps a reason why the Base building is currently not built this way.

The **Zero Energy Ready Home** program mandates the installation of an electrical conduit from roof to electrical panel to enable future installation of a solar photovoltaic system and "clean energy" generation on the building's roof. This effort does not produce any efficiency, or performance improvements on its own but enables "clean energy" generation on the roof if the building is oriented suitably and the roof offers solar potential. As illustrated in

[14] https://www.energystar.gov/newhomes

, the term "Zero Energy" is misleading as **net-zero energy for Green Communities or ZERH is not currently possible in Minneapolis**—even if an entire roof was filled with solar panels and the home not shaded, both of which are typically not possible in Minneapolis' urban core. Additionally, solar photovoltaic systems do not readily provide load shifting (hourly, or seasonally), which means the gaps in heating energy demand as illustrated in chapter 3.4 of this report remain unaddressed.

Passive House is not based on a prescriptive model, but on a series of clear performance targets such as the annual heating energy demand of 15 kWh/ (m^2 a), or 4,75 kBtu/ (sf yr). The Passive House program target has always been informed by the quest for a sweet spot to dramatically reduce heating energy demand and maximize cost efficiency ("Tunneling through the cost barrier"). In a moderate climate zone like the program's origin in Germany the cost efficiency is achieved through omission of a conventional heating system in favor of an extremely efficient building envelope and passive solar heat gains. It is to note that the omission of a heating system is not universally applicable—particularly in much colder climate conditions. Passive House has spurred the development of ultra-efficient building technologies like Passive House windows, airtightness, super insulation, balance heat recovery ventilation equipment among many others. It is significantly changing the paradigms for:

- Ultra-energy efficiency and therefore dramatic reduction of winter peak energy demand on a clean energy infrastructure to meet the global climate-neutrality goal
- Local energy independence and resilience and therefore a potential path to more social justice
- Occupant comfort and indoor environmental quality
- Improved building quality while reducing life cycle ownership cost.

In sum, ultra-energy efficiency like Passive House presents a leapfrog approach over Code and incremental programs such as Energy Star (Green Communities and ZERH).

Table 2 and 3 illustrate the difference in building performance requirements for the envelope and mechanical systems, as well as the resulting energy performance (Table 4).

Table 2: Building performance requirements and recommendations for the building envelope

Envelope Assembly	Base Building	Passive House
Foundation / slab	Not insulated / R-10	Min. R-25
Below-grade wall	R-15	Min. R-30
Above-grade wall	R-13+10, or 20+5, actual R-14[15]	Min. R-50
Roof/ lid	R-49	Min. R-70
Exterior windows	U-factor 0.27 Btu/ (h sf F); SHGC not specified, actual 0.27	Max. U-factor 0.17 Btu/ (h sf F); Min. SHCG (glass) 0.5
Entry door	None	Max. U-factor 0.17 Btu/ (h sf F)
Airtightness	Max. 3.0 ACH_{50}	Max. 1.0 ACH_{50}; recommended max. 0.6 ACH_{50}
Thermal bridges	Not assessed	Thermal bridge-free

[15] The base building does not currently meet Minnesota Green Communities Overlay requirements.

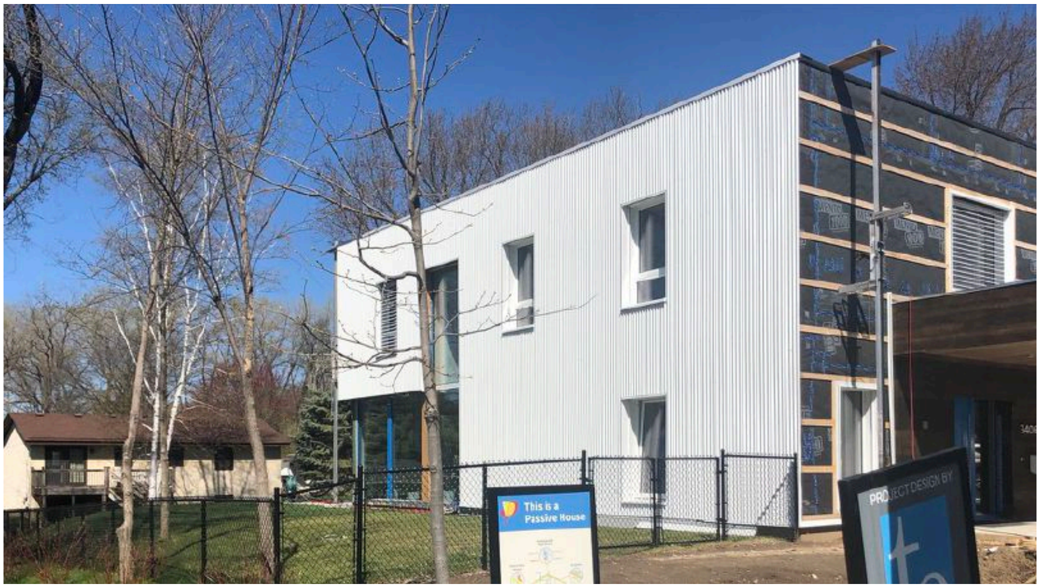

Figure 9: South-facing passive solar facade at the Good Energy Haus under construction

Table 3: Building performance requirements and recommendations for mechanical systems

Equipment	Base Building	Passive House
Whole-house heat-recovery ventilation system	No performance requirements; Connected to heating and cooling system	Performance requirements; Partially connected to heating and cooling system, or stand-alone system (recommended)
Bathroom exhaust fans	One per bathroom with insulated ductwork to exterior	No bath fans; whole-house balanced heat-recovery ventilation system
Dryer	Vented dryer with insulated, ducted exhaust; natural gas	Non-vented dryer; renewable electricity
Kitchen range hood	Insulated, ducted exhaust to exterior	Non-vented, recirculating
Heating and Cooling System	Heating: No COP, natural gas Cooling: Min. SEER 13; electricity	Heating: Min. COP 2.5Cooling: Min. SEER 13; Renewable electricity
Domestic hot water system	EF 0.3 – 0.7; Natural gas	Min. EF 2.0; Renewable electricity
Natural gas infrastructure	Natural gas connection to home including furnace, domestic hot water heater, range and dryer	No natural gas connection and infrastructure in the home

5.2 Observations

5.2.1 Passive House

Based on the contractor RFPs referenced (Figure 12) in this report, the investment in Passive House is approximately $60,000 to 65,000 in comparison to the Base building.

The majority of cost is for passive building systems like; walls, windows (last the life time of the building) and the balanced heat recovery ventilation system. These are the components that provide the leapfrog energy efficiency.

The cost gathered through the RFP reflects "new/ unusual/ unknown pilot project pricing" and not a "production-built" Passive House home.

Past project experience has shown that "early" Passive House pricing can be erratic as substantiated by the builder cost GMHC received.

Other markets have shown, however, that once Passive House projects are built more regularly and market demand changes, first-day cost come down substantially and pricing normalizes. This study does not take any scale effects into account. Anecdotal evidence in other markets has shown that first-day cost for new construction—once common place—can be in single-digit percentage first-day cost increase (thus accelerating payback and further increasing overall life-cycle and societal cost benefits). It is also to note that as building energy codes advance, the investment cost for Passive House building come down further as the difference between a Base building and a Passive House building shrinks. This is evidenced in North American markets with increased building energy codes, or stretch codes such as New York[16], Pennsylvania[17], or Vancouver[18] (BC, Canada) among others.

5.2.2 Zero Energy Ready Home

The requirements for ZERH are the same as Green Communities (Energy Star) plus the addition of a solar photovoltaic system conduit, or an installed system.

A photovoltaic system roof conduit costs on average $300.

Cost for roof-mounted photovoltaic systems was not transparently bid and is contingent on may factors such as solar availability on site, shape, size and orientation of roof, quality of panels and complexity of installation, as well as federal, state, and local subsidies and incentives at time of install.

A net-zero energy (see

[16] https://www.nypassivehouse.org/we-are-extremely-excited-to-announce-the-launch-of-nystretch-energy-code-2020-nystretch/

[17] https://www.phfa.org/forms/multifamily_application_guidelines/submission/01_post_award_req/2015_passive_house_slide_presentationa.pdf

[18] http://www.passivehousecanada.com/wp-content/uploads/2017/11/bcenergystepcode_guide_v1.pdf

) offset on the roof of the Green Communities home is not possible. Even if the upgrades for the better Energy star wall and higher efficiency domestic hot water heating are implemented, the net-zero energy offset cannot be achieved.

A net-zero offset can be provided on the roof when energy efficiency is elevated to an ultra-energy efficient standard, like Passive House.

ZERH can be partnered with Passive House standard as it only requires minimum building performance (Energy Star) and does not limit building efficiency.

5.2.3 Key Observations

In a busy market, it is difficult to solicit RFPs from local builders for "different" projects such as Zero Energy Ready Home and Passive House—particularly if the Projects are a virtual exercise and not a real, or pilot project.

The spread of first-day cost for the Base project in our market is so large that it exceeds the investment in Passive House—therefore pulling into question the approach, and/or the motivation and qualification of the bidders, and rendering the results of this study arguably too soft to inform policy, or ordinance.

5.2.4 Comments

We observe that within our free market economy, and with a stated public preference for "lowest-bidder" project deliveries, the local construction, design and engineering community has value-engineered any tasks that are deemed un-needed away. Over time, this practice created a new building culture in which the "standard of care" and "standard services" are being redefined short of a full scope. While this may superficially improve efficiency and cost, it also means a loss of basic skills, and professional and institutional knowledge, all of which are needed to provide the care and craftsmanship to design, engineer and build quality, high-performance buildings. With the advent of ultra-efficiency standards like Passive House in the United States in the early 2000s, this has become ever more visible in the market place. The deep understanding of building science (no longer taught in architecture schools), combined with a common sense of siting, orientation, material sciences, energy modeling and value engineering to maximize performance and value—not profit margin—is missing, and needs to be rebuilt to answer today's economic, environmental and social challenges in the built environment. This simultaneously presents a challenge and an opportunity to lead the way to sustainability with efficiency, sufficiency and clean energy.

6 Investment, Operating, Carbon and Social Impact Cost

Two rounds of RFPs yielded four replies. In collaboration with GMHC, we analyzed and aggregated the information and summarize our findings (Figure 12: Bid Tabulation Sheet by GMHC).

Base Home

Cost information provided: $278,250.00 to $431,200.00, average of **$333.592.50**

Passive House

Cost information provided: $324,600.00 to $509,765.00, average of **$395,905.00**

Passive House Investment Alternates

Cost information provided: $46,350.00 to $78,565.00, average of **$62,312.50**

Comment: The two biggest investments in the Passive House are the Passive House windows (average of $26,648.50) and the better Passive House wall (average of $25,973.75), followed by the balanced heat recovery ventilation system (average of $4,900.00).

Zero Energy Ready Home photovoltaic system conduit

Cost information provided: $0 to $600, average of **$300**

Zero Energy Ready Home photovoltaic system

Cost information provided: $5,500 to $37,905

Comment: The cost provided is **not relevant** as no specific system capacity was associated by bidders.

6.1 Cost Comparisons

We offer that the current model of investment cost comparisons and simple paybacks does not produce an adequate and realistic picture of cost-efficiency for affordable housing programs, and does not suffice as an active measure to meet global climate targets as proposed by the IPCC. inits place, we created Table 4 and Table 5 to illustrate differences in Initial Investment Cost (2020), Initial Operating Cost (2020), Retrofitting Cost (electrification to meet climate neutrality by 2050), PV Cost (to meet climate neutrality by 2050), Net-Investment by 2020, Net-Investment by 2050, Social Cost of Carbon, Average and Peak Load Size of the Clean Energy Infrastructure (to meet climate neutrality by 2050), Sequestration Needs, and Energy and Social Resilience—in essence a more complete overview of true cost and impact.

Table 4: Cost Comparison 2020 and 2050

	Base Building			Energy Star[19]			Passive House[20]		
2020 (2050) Scenario	**Site Energy**	**Cost**	**ton CO_2**	**Site Energy**	**Cost**	**ton CO_2**	**Site Energy**	**Cost**	**ton CO_2**
Investment cost		**$0**			**$25,000**			**$62,300**	
Heating	24,000 kWh	$960	4.34	20,000 kWh	$800	3.63	2,700 kWh	$324	0.90
Heating 2050	12,0000kWh	$1,440		12,0000kWh	$1,200				
Domestic Hot water	3,000 kWh	$120	1.07	1,000 kWh	$120	0.36	1,000 kWh	$120	0.36
Electricity	7,000 kWh	$840	2.49	7,000 kWh	$840	2.49	7,000 kWh	$840	2.49
Annual total 2020 (2050)	**34,000 kWh**	**$1,920 ($2,400)**	**7.90**	**28,000 kWh**	**$1,760 ($2,160)**	**6.47**	**10,700 kWh**	**$1,284**	**3.92**
Annual energy cost difference to Passive 2020 (2050)		**+ $636 ($1,116)**			**+ $476 ($876)**			**$0**	
Climate-Neutral Scenario 2050	**Site Energy**	**Cost**	**CO_2**	**Site Energy**	**Cost**	**CO_2**	**Site Energy**	**Cost**	**CO_2**
Retrofit cost[21]	-14,000 kWh	$28,000		-10,000 kWh	$18,000		0 kWh	$0	
Net-zero with PV	20,000 kWh	$66,830	0	18,000 kWh	$58,350	0	10,700 kWh	$35,010	0
Roofs needed for annual net-zero[22]	2+			2			1		
PV cost for annual net-zero	17kWp	$94,830		15kWp	$76,350		9kWp	$35,010	
Original building investment cost		$0			$25,000			$62,300	
Total net-zero/ climate-neutral investment cost		**$94,830**			**$101,350**			**$97,310**	

6.1.1 Investment and Operating Costs 2020 to 2050

Investment Costs

The initial investment in Passive House of approximately $60,000 to 65,000 does not reflect the pre-investment made in fossil fuel-free carbon-neutrality by 2050. As illustrated in Table 4 above, all three climate-neutral scenarios reviewed cost about the same (certainly within any reasonable margin of error). However, the first-day costs are ignorant of the 15-30-year replacement cost for

[19] Hypothetical project with Energy Star wall and better domestic water heater not priced. Estimates shown for reference only.
[20] Pilot project pricing assume (not production built)
[21] Assumed COP of 2 for heating and 3 for domestic hot water equipment; heat pump non-vented dryer, electric induction cooktop
[22] Net-zero offset does not mean that a building can operate off-grid. Load-shifting challenges still exist.

mechanical system replacements over time in more conventional buildings (15-30-year useful life) versus the initial investment in passive building envelope systems with a 50-100-year, or longer useful life, among other aspects.

Operating Costs

As mentioned in the introduction, one could make a simple payback analysis based on operating cost savings versus initial Passive House investment costs. However, if this simple payback analysis were made, then it needs to include future cost to become climate-neutral, reinvestment in systems and offsets in clean energy offsets (here with PV) for an apples-to-apples picture. Understanding that the total climate-neutral investment costs are about the same for all three models, the ultimate cost savings are already achieved by the lower operating and reinvestment costs over the life cycle of the building. This demonstrates clearly that:

> **The investment in ultra-efficient Passive House buildings is one of the most life cycle cost-effective climate actions available for immediate implementation.**

Table 5: Climate, clean energy infrastructure and social impact 2020 and 2050

	Base Building			Energy Star[23]			Passive House		
Infrastructure and Social Impact	**Comment**	**Cost**	**f**	**Comment**	**Cost**	**f**	**Comment**	**Cost**	**f**
Social cost of carbon 2020 (political)[24]		$335			$275			$166	
Social cost of carbon 2020 (actual)[25]		$4,740			$3,880			$2,350	
Average Load Increase in today's clean energy capacity			4-5			4-5			2-3
Winter Peak Load Increase in today's clean energy capacity			7-8			6-7			3-4
Peak heat load/ seasonal load shift	Very high			Very high			Low to high		
Sequestration need	Very high			Very high			Low to high		
Energy and social resilience	Very low			low			High to very high		

[23] Hypothetical project with Energy Star wall and better domestic water heater not priced. Estimates shown for reference only.
[24] As provided by the City of Minneapolis
[25] Including current sequestration cost

6.1.2 Climate, Clean Energy Infrastructure and Social Impact 2020 and 2050

In addition to the project specific investment costs, climate, clean energy infrastructure and social impact need to be considered for an evaluation of a true integrated path to sustainability that delivers economy, ecology and social justice. In addition to a tactical "bottom-up" approach, such as the selection of a voluntary building energy standard as discussed in this report, success also requires a true strategic "top-down" understanding and subsequent leadership. We therefore strongly recommend building a clear, strategic understanding of the energy demand components addressed in this report, and in respect to sufficiency and energy efficiency as illustrated in Table 5, before planning and building out the energy supply/clean energy infrastructure.

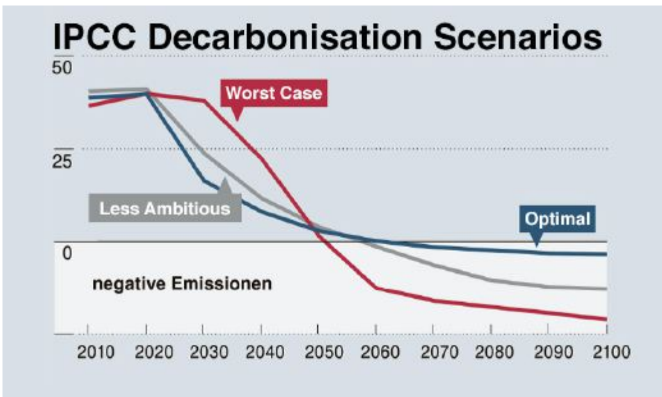

Figure 10: IPCC Decarbonization Scenarios

Climate-Neutrality and Cost of Carbon

The most critical strategic understanding of decarbonization is the current cost of climate action (speed of decarbonization), and the cost to future generations (negative emissions) from sequestration as illustrated in the IPCC's publication Decarbonization Scenarios[26] and illustrated in Figure 10. This fundamentally means:

1. No fossil fuel energy source by 2050, e.g. no gasoline, diesel, natural gas
2. Plus atmospheric CO_2 sequestration, e.g. the longer we wait to eliminate fossil fuel energy sources (optimal vs. less ambitious vs. worst case), the higher the sequestration costs will be to future generations (not including all other negative costs of climate change)

Based on these two principles, we used the Social Cost of Carbon for Minneapolis of $42.46/ ton CO_2[27], as well as current atmospheric sequestration cost of $600/ton CO_2 as published by Climeworks[28] in our review. The comparison illustrates that:

> **The investment in ultra-efficient Passive House buildings is one of the most cost-effective carbon-cost mitigation strategies available for immediate implementation.**

[26] https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15_Chapter2_Low_Res.pdf (page 113)
[27] Provided by the City of Minneapolis Sustainability Coordinator
[28] https://www.climeworks.com

Clean Energy Infrastructure Costs

Learning from electric energy utilities, source energy is only one of the significant cost factors. The other perhaps more important factor is energy demand, and in particular, peak energy demand (see Figure 1). For example, the current electrical grid and capacity is designed to meet peak summer cooling load. Therefore, meaningful climate action is not only a function of the implementation of clean energy sources, but more so the meeting of the actual energy demand (optimized by efficiency and sufficiency measures), achievement of daily, and seasonal load-shifting, and therefore the investment in a clean energy infrastructure as outlined in chapter 3.6.

A future climate-neutral clean energy infrastructure ("electrify everything") will be dictated largely by peak heating load and as such, will be largely defined by the quality and performance of the building stock (as shown in Figure 1 to Figure 4). Therefore, all efforts in building efficiency and sufficiency will affect the size and therefore investment costs for the clean energy infrastructure (as shown in Figure 6). The table illustrates that:

> **The investment in ultra-efficient Passive House buildings is a sound strategy to ensure adequate build-out and mitigation of the risk of over-investment in a clean energy infrastructure.**

Social Impact and Social Justice

Learning from the systemic discrimination problems in our society and the dramatic climate action challenge ahead, one could argue to use this pivotal moment in time for the dramatic changes required by climate change actions, as well as an opportunity for cultural and societal change. In this regard, efficiency and sufficiency could become new cultural values required by society/ communities and as a result, reduce an economic, social injustice and environmental footprint gap. Lower energy use, operating and life cycle cost favor a more socially just community. Therefore:

> **The investment in ultra-efficient Passive House buildings delivers meaningful climate action with the lowest social impact.**

Economic Impact and Opportunities

Some argue that we cannot afford climate action. For instance, the local building industry appears to fight for lowest investment cost under the pretense that higher investment cost will turn our economic engine off. Considering actual societal costs as demonstrated in this report (investment, operating, ownership, infrastructure, social and environmental) one could also argue that this is a penny-wise and dollar-foolish argument. Considering also future divesting from fossil fuels, one could ask what that money and those investments will be shifted to.

Understanding the need for climate-neutral new construction (as well as retrofitting) as outlined in this report to meet IPCC climate-neutrality goals by 2050 creates significant growth opportunities for the construction sector. We estimate a 3 to 5-fold increase in building activity in the next 30 years. The construction market in the Twin Cities is currently at capacity, and facing the challenges and opportunities outlined in Chapter 4.3. Herein lies a chance to ideally position our community and take advantage of future economic opportunities through an understanding of these new market dynamics, and the demonstration of clear leadership for a climate action plan, which supports a vibrant and just economic environment and market for all constituents.

The investment in ultra-efficient Passive House buildings provides immediate climate action and offers tremendous economic opportunities for our community.

6.2 Recommendations

6.2.1 Efficiency

Set clear, measurable and verifiable climate action targets including heating and other energy demands for buildings. This provides a benefit to all developers and owners, as well as Minneapolis departments like CPED to implement the Climate Action Plan. It also helps to benchmark the many sometimes confusing building standards and programs in the market place and enables sound selection of cost-effective, climate-neutral approaches such as Passive House.

6.2.2 Sufficiency

Start a political dialog to initiate a new culture of sufficiency in affordable housing through investigation of size, amenities, clustering (multi-family buildings offer 2 units for the price of 1 single family home) and other new forms of housing, work, shop, transportation, urban agriculture, etc. to find more cost effective solutions using less energy while improving the quality of life, providing economic benefits, social justice and conserving the natural environment.

6.2.3 Pilot and Lighthouse Projects

Turn climate targets into clear, measurable and verifiable requirements for all buildings in the City of Minneapolis and use City-funded projects such as the ones led by CPED as pilot and "lighthouse" projects (= become market leaders). Built pilot projects entice the market place, lead the way, inspire and pave the way for cost optimizations and roll out.

6.2.4 Monitoring, Closing the Loop

Monitor projects and compare with national and global reference targets to improve the three pillars of sustainability:

- Economy (First-Day Cost, Operating Cost, Economies of Scale…)
- Environment (Climate Impact, Clean Air, Clean Water, Clean Energy…)
- Social Impact (Resilience, Social Justice, Human Health…)

Monitoring creates a basis for cost and performance optimizations, as well as a feedback loop to assure stakeholders successful implementation of sustainable projects and achievement of the targets set in 6.2.1, tested in pilot projects described in 6.2.3 and implemented during the roll-out outlined in 6.2.5.

6.2.5 Minneapolis Passive House Roll-Out

Define and refine ultra-energy efficient Passive House buildings based on Minneapolis' Climate Action Plan for all building projects including sustainable, affordable housing. Put measures into place to ensure quality control and verify results in the field, such as third-party certification and field testing as part of the City inspections process.

7 Barriers in Minneapolis

As part of the approval process for the first certified new-construction Passive House building—the Good Energy House in Northeast Minneapolis—we provided a Feedback Matrix (Figure 11: Comparison Matrix) to illustrate and communicate current barriers. The matrix also holds recommended solutions to overcoming those barriers. It was answered by City staff at the time and includes staff comments. The document was circulated to the Departments of Health, Sustainability, CPED, Zoning, Inspections as well as City Council. It is attached to this report for reference.

8 City Staff Training

We recommend a variety of presentations and training for City leadership and staff:

Climate Action Goals and Targets, Workshop for City Leadership

Inform, recommend and solicit input in regards to **demand and supply based climate action** goals and targets

Climate Action Goals and Targets, Workshop for City Staff

Inform, recommend and solicit input in regards to current climate action limitations and opportunities for change

Passive House, Ultra-Energy Efficient Buildings Implementation Barriers, Workshop for City Staff

Review and understand barriers in Minneapolis in respect to ultra-energy efficient buildings – like Passive House. Review of Policy Resources such as NAPHN's policy resource guide.[29]

Passive House Training

Attend CPHD and CPHT training courses provided by NAPHN[30] as they pertain to position, department and role

Passive House Webinars, Conferences and Workshops

Attend national and international Passive House webinars, conferences and workshops as hosted by the international Passive House Association[31], NAPHN, and other organizations.

29 https://drive.google.com/file/d/1x49Xmey6qaqfG-XDhzvq4TfbdTqhvi0a/view
30 https://naphnetwork.org
31 https://passivehouse-international.org

A Addendum

METRIC	MN CODE (2015 / climate zone 6)	ENERGY STAR FOR HOMES 3.1	GREEN COMMUNITIES	ZERO ENERGY READY	ACTUAL BASE	PASSIVE HOUSE (Intep)
ENERGY & PERFORMANCE						
Energy			Energy Star 3.1 New Homes Program	Energy Star 3.1 New Homes Program	not met	
Energy Star Thermal Enclosure System Checklist						
HERS Rating Report/ Energy Model Energy Star for Homes						
Energy Modeling			Manual J, or S, or ASHRAE	HERS Rating		PHPP
BUILDING ENVELOPE						
Insulation Roof - R	49	49	49	49	50	approx. 80
Roof - U		0.026	0.026	0.026		
Insulation Wall above grade	20+5, or 13+5	20+5, or 13+9	20+5, or 13+9	20+5, or 13+9	19	approx. 50
Wall - U		0.048	0.048	0.048		
Construction					16" o.c. 2x6 wall	24" o.c. 2x6 advanced stick framing
Insulation Wall below grade	15	15/18	15/18	15/18	15	approx. 30
Wall - U		0.05	0.05	0.05		
Insulation Slab	10	10	10	10	10	approx. 25
Slab - U						
Windows						
Window U-value, NFRC	0.32	0.27	0.27	0.27, or 0.28. 0.29, 0.30		0.11 - 0.16
Window SHGC, NFRC	Any	Any	Any	any, or 0.32, 0.37, 0.42		> 0.35
Door U-value		0.17	0.17			0.14
MEP SYSTEMS						
Ventilation						
Ventilation Equipment heat recovery				60% SRE		80% (PHI)
Ventilation Equipment motor efficiency				1.2 CFM/ Watt		0.45 W/ m3
Ventilation System					exhaust from bath, kitchen range hood exhaust and Venmar heat recovery ventilator?	balanced ERV system
Ventilation Capacity						30m3/ h per person + add criteria
Ventilation system commissioning						Required
Cooling Equipment						
Cooling Equipment		13 SEER electric AC	13 SEER electric AC			electric AC
Heating Equipment,						
Heating Equipment, gas furnace		95%	95%	94%		
Heating Equipment, gas boiler		90%	90%	94%		
Ground source electric heat pump		3.6 COP/ 17.1 EER	3.6 COP/ 17.1 EER	3.6 COP/ 17.1 EER		
Ground source electric air to air heat pump		9.5 HSPF/ 15 SEER/ 12 EER	9.5 HSPF/ 15 SEER/ 12 EER	10 HSPF/ 13 SEER		
Programmable thermostat		Required		Required, except radiant heat		
Ducts in conditioned space		Required		Up to 10' exterior		
Ducts airsealed					no	yes
SA ducts insulated					no	yes
Hot Water heat pump system						
Hot Water Heater gas propane <55 GAL		EF 0.36 - 0.61		EF 0.67	50GAL, direct vent, 0.72 EF	
Hot Water Heater gas propane >55 GAL		EF 0.36 - 0.61		EF 0.77		
Hot Water electric detached		EF 0.89 - 0.94		EF 2.0		
Hot Water heat pump system						electric heat pump
EXECTUTION, QUALITY AND CHECKS & BALANCES						
Thermal Bridges		N/A	N/A	N/A	YES	free
Installation quality				Grade 1		Grade 1
Blower Door Test	3.0 ACH50		3.0 ACH50	2.0 ACH50	1.5 ACH50	0.6 ACH50 (new)
Blower Door Test certificate			Documents must not be submitted unless requested by Minnesota Housing. The Administrator must retain this document in the project file for compliance. Only required if applicable.			Required, specific testing protocol
Certification		Required	Encouraged but not required			Not required
Submittals			Intended Methods Worksheet			
USER EQUIPMENT						
Appliances		Energy Star	Energy Star	Energy Star		Per designer
Range hood					exhaust	non-venting
Dryer					gas, venting	electric non-vented
Lighting			Follow the guidance for high-efficacy lighting controls and other characteristics for any new permanently installed lighting fixtures in project dwelling units, common spaces and exterior.	Energy Star		
Metering			1 Meter per leasable unit			
RENEWABLE INFRASTRUCTURE						
Renewables				Checklist, energy can be purchased (then do not need PV ready checklist)		Opional, system installed and modeled to achieve Premium and Plus standard

Figure 11: Comparison Matrix

BID TABULATION SHEET

Date: April 23, 2020 Time: 3:00 PM

Property Owner: Greater Metropolitan Housing Corporation

Improvement Address: 2946 Queen Avenue North, Minneapolis

Amouncement:

Although these bids are being publicly opened and read, The Greater Metropolitan Housing Corporation (GMHC) and its Agents and Assigns does not waive any informalities with respect to such bids. GMHC and its Agents and Assigns reserve the rights to reject any or all bids l bids and to waive any informalities in the bidding. The bid results will be available at the GMHC Downtown Office for public inspection.

Contractor Name	Base Bid	Alternate #1 Vinyl Siding	Alternate #2 Handicapped Ramp	Alternate 2.1.1 Foundation Subtract	Alternate 2.1.1 Foundation Add	Alternate 2.1.2 Below Grade Wall Subtract	Alternate 2.1.2 Below Grade Wall Add	Alternate 2.1.3 Above Grade Wall Subtract	Alternate 2.1.3 Above Grade Wall Add	Alternate 2.1.4 Roof Subtract	Alternate 2.1.4 Roof Add	Alternate 2.1.5 Windows and Doors Subtract	Alternate 2.1.5 Windows and Doors Add	Alternate 2.1.6 Airtightness Subtract	Alternate 2.1.6 Airtightness Add
JPS Remodeling	$278,250.00	-$18,000.00	$7,500.00	-$1,300.00	$3,200.00	-$4,000.00	$5000.00	-$4200.00	$24200.00	-$1,400.00	$2,000.00	-$7,000.00	$22,000.00	-$500.00	$1,000.00
Lutz Construction	$189,225.00	-$5,200.00	$7,500.00	-$1,500.00	$8,500.00	-$2,500.00	$6500.00	-$2900.00	$24000.00	-$1,200.00	$3,800.00	$0.00	$0.00	-$210.00	$1,200.00
Lewis Building & Remodeling	$135,695.00	-$19,895.00	$8,000.00	-$1,300.00	$5,300.00	-$5,300.00	$12,056.00	-$4200.00	$27,695.00	-$1,400.00	$0.00	-$11,600.00	$32,440.00	-$500.00	$1,500.00
KMK Builders	$431,200.00	-$1,512.00	$2,250.00	-$1,322.00	$3,000.00	-$2,500.00	$5000.00	$0.00	$26000.00	-$884.00	$1,326.00	-$5,439.00	$52,154.00	-$510.00	$1,000.00
Terra Firma	No Bid Submitted														
Braden Construction	No Bid Submitted														
Tamer Construction	No Bid Submitted														
Porchlight Construction	No Bid Submitted														
Yanz Builders	No Bid Submitted														
Sustainable Design Build	No Bid Submitted														
Karon Custom Build	No Bid Submitted														
Sean McCloughin	No Bid Submitted														
JM Construction	No Bid Submitted														
Woodcrest Builders	No Bid Submitted														
Bencz Homes	No Bid Submitted														
Aaron Cornell	No Bid Submitted														
Average Price	$333,592.50	-$11,101.75	$6,312.50	-$1,355.50	$5,000.00	-$3,575.00	$7137.50	-$2800.00	$25973.75	-$1,221.00	$1,706.50	-$6,259.75	$26,648.50	-$437.50	$1,175.00

Contractor Name	Alternate 2.1.7 Thermal Bridging Subtract	Alternate 2.1.7 Thermal Bridging Add	Alternate 2.2.1 Natural Gas Infrastructure Subtract	Alternate 2.2.1 Natural Gas Infrastructure	Alternate 2.2.2 HRV Subtract	Alternate 2.2.2 HRV Add	Alternate 2.2.3 Hvac System Subtract	Alternate 2.2.3 Hvac System Add	Alternate 2.2.4 Domestic Hot Water Subtract	Alternate 2.2.4 Domestic Hot Water Add	Alternate 2.3.1 Range Subtract	Alternate 2.3.1 Range Add	Alternate 2.3.2 Clothes Dryer Subtract	Alternate 2.3.2 Clothes Dryer Add	Alternate 2.4 Zero Energy Ready Add	Alternate 2.4 Zero Energy Ready PV Add	Total Alternates 2.1.1-2.3.1	Total Base And Alternates 2.1.1-2.3.2
JPS Remodeling	$0.00	$1,700.00	-$800.00	N/A	-$1,400.00	$2200.00	-$4,500.00	$9,000.00	-$1,600.00	$2,800.00	-$800.00	$1,580.00	-$250.00	$1500.00	$600.00	$5,500.00	$45,350.00	$324,600.00
Lutz Construction	$0.00	$0.00	-$2,600.00	N/A	-$3,600.00	$15,000.00	-$6,100.00	$22,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$58,750.00	$347,975.00
Lewis Building & Remodeling	$0.00	$2,400.00	-$910.00	N/A	-$1,400.00	$2400.00	-$6,500.00	$10,600.00	-$1,600.00	$2,800.00	-$250.00	$1,880.00	-$250.00	$1800.00	$600.00	$7,800.00	$65,585.00	$401,280.00
KMK Builders	$0.00	$0.00	-$1,355.00	N/A	$0.00	$0.00	$0.00	$3,655.00	-$2,400.00	$0.00	$0.00	$0.00	-$170.00	$0.00	$0.00	$37,305.00	$75,565.00	$509,765.00
Terra Firma																		
Braden Construction																		
Tamer Construction																		
Porchlight Construction																		
Yanz Builders																		
Sustainable Design Build																		
Karon Custom Build																		
Sean McCloughin																		
JM Construction																		
Woodcrest Builders																		
Bencz Homes																		
Aaron Cornell																		
Average Price	$0.00	$1,325.00	-$1,213.75	$0.00	-$1,600.00	$4900.00	-$5,275.00	$11,313.75	-$1,400.00	$1,350.00	-$262.50	$825.00	-$167.50	$825.00	$300.00	$12,601.25	$62,312.50	$395,905.00

The Original round of bids were solicited in Finance and Commerce

Bids opened by: Curt Bennett

Bids recorded by: Curt Bennett

Figure 12: Bid Tabulation Sheet by GMHC

Good Energy Haus - Passive House Pilot Project. Worksheet for City of Minneapolis by TE Studio — Oct. 10, 2018

No.	Item	TE Studio (Finding)	TE Studio (Pilot Project Ask)	City of Minneapolis (Immediate Pilot Project Response)	Future change (Mid to Long term Action item)	Responsible Party
Zoning						
1.01	Zoning: Heights	Heights and roof pitches can be limiting when designing passive solar structures in the urban environment	Allow taller maximum heights and alternate roof pitches and shapes to enable maximum passive and active solar radiation yield on site (this is not expected to be an issue with the Good Energy Haus pilot project)			
1.02	Zoning: Setbacks building placement	Setbacks can force buildings further to the south lot line than needed, reducing passive solar heat gains, views and creating privacy issues	Allow setback reductions to maximize passive solar heat gains on south side (Would it be acceptable to reduce the north setback from 8 to 5, or 6 feet?)			
1.03	Zoning: Setbacks encroachment of assemblies, structures and devices	Retrofits in the setback are looked at as "additions" to a structure	Allow setback reductions for retrofit assemblies and shade structures/ devices (not an issue on the Good Energy Haus, often a retrofit issue)			
1.04	Zoning: Fenestration	Required fenestration—particularly on the north, east and west facades—produce excessive heat loss, heat gains and require great expense for Passive House windows and exterior shade systems; first day and operationg cost are inflated	Allow alternate fenestration percentages (reduce required minimum on north, east, and west facades)			
1.05	Zoning: Energy Efficiency	No points are awarded for energy efficient buildings on Minneapolis development checklist, nor is energy efficiency at any level a requirement	Mandate minimum energy efficiency standard and award points towards development point system for Passive House construction			
Building Inspections						
2.01	Permitting: Energy	In the past, we had to fill in energy worksheets, or use a crude and basic energy assessment tool when we produce a very detailed energy model with the PHPP	Allow PHPP energy calculations in place of any other energy worksheets	Submit form format and we can evaluate for code compliance.		
2.02	Permitting: Building Science (hygrothermal performance)	In the past, inspectors questioned Passive House assemblies including vapor transmission, airtightness, material properties and layering of assemblies	Allow modeled, super-insulated, airtight Passive House assemblies in place of prescriptive vapor retarder on inside face of wall	We would review a modeling proposal as an alternate. Could possibly receive department approval as an alternate standard.		
2.03	Permitting: Buiding Science (insiation value)	Conventionally, R-values are given based on the insulated part of cavity construction only	Accept whole-assembly R-value metric in place of insulation thickness	We can accept.		
2.04	Permitting: Windows	Generally, the market place and any incentive programs favor low insulation, low solar heat gain glazing and very poorly performing frames; no requirements for frame u-factor and glazing spacers were found	Accept and incentivize installation of Passive House with solar heat gain glazing, super spacers and exterior shading strategy	Could review solar heat gain glazing / exteriorshading as an alternate.	Incentivizing Passive House would require city ordinance change.	
2.05	Permitting: Airtightness	The current mandated airtightness of 3.0 ACH50 (small scale residential buidings) is concerning when empirical buiding sciens finds that this is perhaps an "unsafe" level or airtightness	Mandate 1.0 ACH50, or better (for smaller buildings, custom values for larger buildings) airtightness requirement	Beyond code minimums	Would require state code change.	
2.06	Permitting: HVAC - Ventilation Strategy	Now that air-tighter buildings are stipulated by code, exhaust-only ventilation strategies cause buiding science issues and energy inefficiencies	Mandate high-efficiency, whole house heat-recovery ventilation in place of exhaust only systems without heat recovery	HRV or ERV systems are required in new construction.		
2.07	Permitting: HVAC - Ventilation - Tubing	Sheet metal ductwork is leaky and cumbersome. It is not cost effective and efficient for moving ventilation air	Allow PE ventilation tubing in place of sheet metal duct work	Submit a proposal for preliminary review for us to determine product compliance.		
2.08	Permitting: HVAC - Mechanical Protrusions	Some mechanical potrusions are legislated to be uninsulated and airsealed	Allow insulation and air-sealing around mechanical protrusions with appropriate products	Not aware of prohibitions to insulate.		
2.09	Permitting: Plumbing - Pipe insulation (stacks)	Some stacks are mandated to be uninsulated. All stacks that exit the buildings are thermal bridges and potential air leaks	Allow and mandate insulation around vent stacks, which protrude the building envelope (plumbing, radon)	Not aware of prohibitions to insulate.	Mandating the insulation as proposed would require a change to the state code.	
2.10	Permitting: Plumbing - Pipe insulation (hot and cold)	Cold water lines can sweat, hot water lines heat buildings inadvertently	Mandate hot and cold water to be continuously insulated	Hot water piping is required to be insulated per the Energy Code section 403.4. Cold water piping is not required to be insulated.	Mandating the insulation as proposed would require a change to the state code.	
2.11	Permitting: Plumbing - Radon System	Radon systems can impact the pressure balance in buildings and become thermal bridges	Allow radon mitigation via soil gas membrane and by dilution in place of sub slab mitigation	Passive radon system is required as described in Residential code per 1303.2402. This system would be an alternate to the code.	State code change	
2.12	Permitting - Plumbing Vents	Plumbing stacks that exit the building are generally thermal bridges with very little benefit	Allow air admittance valves in place of plumbing stack wherever technically feasible	Air admittance valves are not permitted per State Statute 326B.43 Subd 6.	Change to state code would be needed.	
2.13	Permitting: Appliances	Exhaust only devices do not work in airtight buildings	Require ventless dryers in place of vented dryers; eliminate other exhaust-only devices	Dryers are required to be exhausted but there is an exception allowing listed labeled condensing ductless dryers. Mech. Code section 504.1.	Change to state code would be needed.	
2.14	Permitting: Fees	High-performance buildings cost more on day one; most fees are based on project cost, inadvertently penalizing high-performance building owners	Exclude increased cost from permit cost assessment		Change to city fee ordinance	
2.15	Permitting: Process (Alternates)	In case where standard practice is in conflict with Passive House building, the burden of proof falls on the project team to map out alternates. This causes additional work and cost createing a disincentive to owners	Remove the burden from those who exceed requirements and put it on those who barely meet minimum requirements	Alternates could be proposed as a allowed standard rather than as a case by case basis.		

Figure 13: Passive House Feedback Matrix

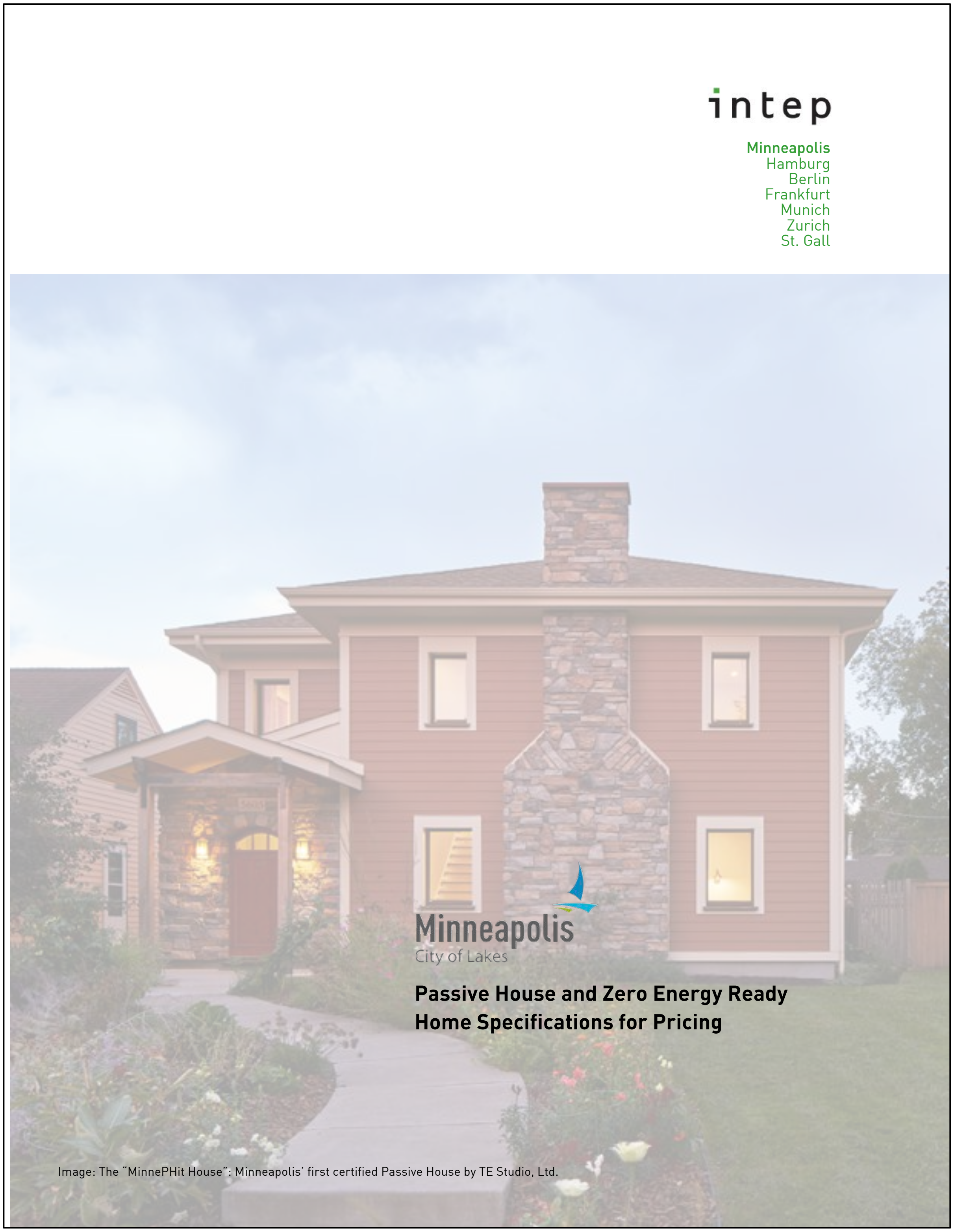

Figure 14: Passive House and Zero Energy Ready Home Specifications for Pricing